

Workflow Management of HIS/RIS Textual Documents with PACS Image Studies for Neuroradiology

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ABSTRACT

Reviewing brain tumor patients' complete medical record is a daunting task for any clinician. In current practice, the radiologist examines the most recent documents and then dictates an assessment of the patient's condition based on a review of the most current imaging study and compared with the most recent previous image study. Occasionally, the radiologist searches other clinical documents when more precise detail is needed. The purpose of this research is to develop effective methods to review all of the pertinent information in a patient medical record incorporating HIS (Hospital Information Systems), RIS (Radiology Information Systems) and PACS (Picture Archiving and Communications Systems) information in three distinct ways: filtering the document worklist for pertinent clinical data, identification of key clusters of clinical information, and an automatic hanging protocol that displays the MR images for optimal image comparison.

INTRODUCTION

In the final report of the Committee on Quality of Health Care in America, one of the key recommendations for fundamentally changing the inadequate quality of care within the American healthcare delivery system is to commit to building an information infrastructure to support health care delivery, consumer health, quality measurement and improvement, public accountability, clinical and health services research, and clinical education¹. This recommendation is specifically targeted towards the development of an effective and efficient information technology infrastructure. A major step toward a better information technology infrastructure within healthcare was the advent of converting film-based radiology into all

digital imaging. At UCLA, the initial development of a pediatric PACS systems in 1985 was the first steps in digitizing all diagnostic images. The next major progression in improving the information technology infrastructure, especially within many modern radiology departments, is the integration of HIS, RIS and PACS into the radiology workflow, with the goal of moving toward a paperless work environment. HIS, RIS and PACS vendors over the last 5 years are working on forming partnerships to insure that the integration is feasible. IHE (Integrated the Healthcare Enterprise) initiative funded by RSNA (Radiological Society of North America) has been working with HIS, RIS and PACS vendors since 1999 to show the feasibility of HIS, RIS and PACS integration with live demonstrations of working systems from different vendors at RSNA's annual meeting².

Allowing access to all the alphanumeric as well as image data will not necessarily improve the quality of healthcare if the information cannot be structured and rendered more efficient for the clinician to view and understand. The reality of providing access to all medical documents electronically is another conduit of information that can easily overload the clinician. In addition, PACS workstations that accommodate some clinical document access, typically historical radiology reports, lack any substantial data integration between the image and alphanumeric information. There is a need to improve the interface design to the patient's complete medical record in order to allow the clinician to fully integrate the information in accessing the patient's diagnosis^{3,4,5,6}.

Typically, the weakest level of integration of HIS, RIS and PACS commonly infers that one can view the individual data on independent systems. From the PACS workstation, one can

view images and then from another computer, typically through a web browser, the alphanumeric clinical documents can be viewed. Our hypothesis is that strong integration of HIS, RIS and PACS data can improve the efficiency of the neuroradiologist's workflow as well as effectiveness of the dictated radiology report

METHODS

Seventeen different brain tumor patients diagnosed with a meningioma were used in the study. The medical record system at UCLA was queried for all clinical documents. Specifically, a patient's medical record consists of radiographic images which may include anatomical and/or functional modalities: MR (magnetic resonance), CT (computed tomography), CR (computed radiography and PET (positron emission tomography). In addition, a patient's clinical documents can include: physician inpatient and outpatient notes, radiology reports, pathology findings, surgical notes, radiation oncology reports, and laboratory results. In general, EMR (electronic medical records) are difficult to construct because the existing data sources are isolated databases within each department with differing interface protocols⁷. A key component within our research laboratory that addresses the retrieval of information from disparate sources led to the development of DataServer⁸. DataServer provides access to all clinical images and alphanumeric documents for a patient.

The objective of our research is to create intelligent data integration in order to provide a neuroradiologist with the necessary information to facilitate workflow in the evaluation of brain tumor patients. The following is a neuroradiologist's workflow process when dictating a report on a patient's current image study.

1. Browse and select patient on a document worklist who has an unread imaging study.
2. Select and review current image study.
3. Compare current study to previous image studies.
4. Find pertinent clinical documents to help understand indication for current study.
5. Search for key interval therapies: surgery and/or radiation that may alter imaging appearance.
6. Dictate radiology report with findings

7. Consult with referring physician or other specialist concerning progression/regression of disease.

Filtering the Worklist: Finding pertinent documents reduces the overhead of the clinician from sorting through unnecessary documents for clinical detail. We have developed an index and mapping algorithm to parse each clinical document to identify key terms using a semantic filter that allows general queries based on semantic types defined within UMLS (Unified Medical Language System)⁹. Table 1 shows an example of semantic types used to filter the clinical documents. Table 2 shows the output from the filtering process for a radiology document. Documents that contain the output descriptor from the indexing and mapping algorithm are then used to search all documents. Those documents containing the key words are added to the neuroradiology worklist for inclusion.

Table 1. Semantic type filters for general queries of the clinical documents.

Brain Tumor Characteristics to Search for	Semantic Type
Specific Cancer	Neoplastic Process
Medical Intervention	Therapeutic Procedure
Anatomical location	Body Part, Organ or Organ Component

Table 2. Output values from filtering of the UMLS document.

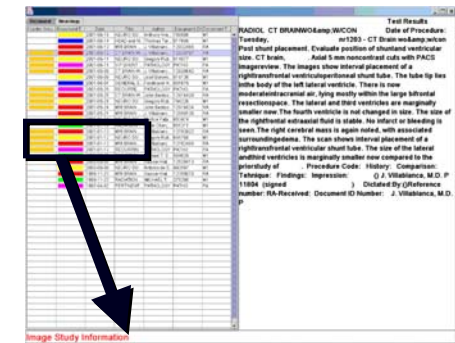
Semantic Type	Output Descriptor	ULMS code
Neoplastic Process	meningioma	C0025286
Therapeutic Procedure	craniotomy	C0010280
Disease or Syndrome	hydrocephalus	C0020255

Figure 1 shows an example of an unfiltered worklist. In comparison, figure 2 shows the worklist after removal of documents that did not contain the key words: meningioma, hydrocephalus, and/or craniotomy. The original

worklist contains 46 documents, after filtering the new worklist contains only 26 documents.



Figure 1. All medical documents for a typical brain tumor patient. The left panel lists 46 clinical documents. The right panel shows contents of a pathology report.



		2001-01-18	RADIATION ...
		2001-01-13	MRI BRAIN ...
		2001-01-12	NEURO SU...
		2001-01-12	MRI BRAIN ...
		2001-01-12	RECURRIN...
		2000-08-21	RADIATION ...

Figure 2. The left panel lists 26 automatically filtered pertinent brain tumor documents. The right panel displays contents of selected radiology report. The bottom panel shows the enclosed boxed area of the worklist magnified.

Clustering the Information: Completion of the document filtering allows clustering of key medical events. The removal of unnecessary documents allows for simpler rules to group documents around key medical therapeutic events. Figure 2 shows the clustering in the lower panel. The color code in column two for each type of clinical document follows the following format: radiology documents (red), neurosurgery documents (yellow), pathology reports (purple), radiation oncology notes (green), and miscellaneous documents (blue).

Clusters of documents are based on simple rules for collecting clinical documents that span a specified time period. A clustering based on a surgical event requires two imaging studies, a neurosurgery document and a pathology report. The clustering of clinical documents that identify a surgical event is shaded orange in column one of figure 2. All 12 permutations of size 4 taken from 3 distinct objects are valid clusters. The time span for acceptable clusters is based on the difference between the most current document and the oldest document.

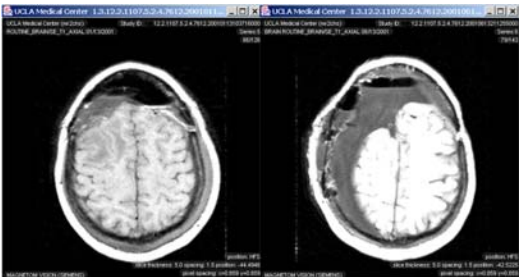


Figure 1. (Left Image) Post-surgical image study 1-13-2001 (2D Axial T1 Spin Echo). (Right Image) most recent image study 6-13-2001 (2D Axial T1 Spin Echo).

Hanging Protocol: On completion of the information clustering, the radiologist can now select the document clusters of interest to view. At readout, the current image study requires the radiologist to carefully assess each image within the dataset. For our seventeen cases, the average number of images for an MR study was 141 ± 48 and for CT studies 51.6 ± 49.2 . One of the most time consuming steps in the image review process is the manual configuration of the display software to allow side by side comparisons of multiple image studies. Typically the neuroradiologist will display the current and most recent prior image study, and then individually compare each image of the current image study with similar images from the previous study to determine interval change in the brain tumor. The proper formatting of the image display for viewing an image study is also known as a hanging protocol. Our automatic hanging protocol developed previously aids the neuroradiologist by matching up similar series within the image study¹⁰. The hanging protocol automatically sorts the image series so that side-by-side comparisons of individual images from similar image series from different image studies can be compared.

For example, figure 1 shows the automatic hanging protocol for side-by-side comparison of the post-surgical and current image study. The differential diagnosis shows a return of the tumor after 5 months. The radiologist has full control over each individual image for basic image operations such as: rotation, scale, pan, window and level, cine mode, linear measurements, and display formats (1 on 1 or 4 on 1). The individual image series can be linked so that the cine operations can be simultaneously applied to both image series for easier review.

RESULTS

Results of applying our filtering algorithm to 17 brain tumor patients all diagnosed with meningioma are shown below in table 3. The average percent reduction in documents for each patient was 46.7% ($\pm 13.7\%$).

Table 3. Statistics of pre and post filtered clinical documents of 17 brain tumor patient with meningioma.

Type of Documents	Total No. of Documents	Average No. of Documents per patient
All Document Types	399	24 ± 19
Filtered Documents Neurological Only	192	11 ± 7

In order to determine the accuracy of the filtering process two experienced (11.5 ± 2.1 years) neuroradiologist reviewed the document worklist for all 17 patients. The neuroradiologists determined if the documents were omitted from the filtered list or were unnecessarily added to the worklist. Table 4 summarizes the effectiveness of our filtering process. Our simple filtering process on key word searching is effective at minimizing the number of unnecessary documents, but at the expense of omitting 3x as many documents. There are three main reasons for omission of documents: missing document titles, inaccurate document titles, new document discovered during the filtering process. When documents are retrieved from DataServer, the individual documents contain a title field. The primary error (18%) was in neurological consults that

were omitted because of misidentified, misleading or missing document titles. The neuroradiologists also concluded that MR angiograms, MR functional imaging, and X-ray images of the skull (26% of the omission error) should have also been included in the neuroradiology document worklist. The previous errors can be corrected by expanding our keyword search through all document irrespective of the document title. The most difficult error to resolve is corresponding signs and symptoms for the disease, which are varied and subtle in description. These errors cannot be handled by a simple keyword search, but will require the use of more sophisticated techniques such as natural language processing to resolve.

Table 4. Errors in document filtering (N = 17 patients, 399 documents).

Error Type	Total No. of Errors for All Patients	Avg Error per Patient	Percent Document Error Per Patient
Omission of Documents	43	3 ± 3	22.2%
Unnecessary Documents	14	1 ± 1	7.8%

CONCLUSION

We have developed a new filtering and classification scheme based on HIS, RIS and PACS information. This filtering scheme reduces the number of relevant documents related to a brain tumor case. The filtering process significantly reduces the number of relevant clinical documents related to the patient problem. After identification of each document type, clusters of surgical interventions that are important in understanding the diagnosis of a brain tumor patient are identified. The hanging protocol is then tailored to view the image studies based on the filtered and clustered document structure.

FUTURE WORK

We are in the process of evaluating our proposed HIS, RIS & PACS neuroradiology workstation and have performed evaluations on the current PACS workstation used clinically at UCLA. The goal of the study is to compare time efficiency and user satisfaction surveys on both HIS, RIS & PACS workstations.

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